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Study on the influence of ocean engineering on the navigation safety of surrounding waters

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Study on the Influence of Ocean Engineering on the Navigation Safety of Surrounding Waters

By

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The People's Republic of China

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

(Signature): ...Liu. Zhaonan....................................

(Date): .... June.29th.......2017.............................

Supervised by Professor Fu Yuhui

Dalian Maritime University

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ABSTRACT

Title of Research paper: **Study on the influence of Ocean Engineering on the navigation safety of surrounding waters**

Degree: **MSc**

Ship derives from the prehistoric wood for the boat, and went through the canoe and wooden boats times. In 1879, the world's first steel ship came out and began to ship steel dominated era. The advance of the ship by nineteenth Century from relying on human, animal and wind, to drive with the use of machinery; and over the past century, the shipping industry has developed rapidly, and still maintained a strong upward momentum. However, the higher and higher ship density brought the problem of navigation safety.

Ocean engineering is the method for human to utilize the marine resource. Marine resources refer to one of the categories of natural resources, including sea life, chemical elements dissolved in seawater, sea waves, tides and currents generated by the energy storage and heat contained in coastal and continental shelf and deep-sea mineral resources, etc. As early as prehistoric times, human had travelled on the ocean, fished from the sea, and exploring the oceans; marine resources is more and more important for people in this age of scarce resources.

As road construction will affect road traffic, ocean engineering will also affect marine traffic, and endanger navigation safety. This article focuses on the influence resulting from ocean engineering to the navigation safety, calculating the degree of influence by means of IWARP model, and presenting recommendation by the application of AIS for minimizing the negative influence.

Key words: marine traffic; navigation safety; ocean engineering; collision casualty; IWARP; AIS

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LIST OF ABBREVIATIONS

CIA	Central Intelligence Agency
SMS	Safety Management System
TNO	Netherlands Organization for Applied Scientific Research
IWARP	IALA Water Risk Assessment Program
AIS	Automatic Identification System
VTS	Vessel Traffic Service
V&W	Ministerie van Verkeer en Waterstaat
ROV	Remotely Operated Vehicles
MROV	Marine Remotely Operated Vehicles
NOAA	National Oceanic and Atmospheric Administration
MSA	Maritime Safety Administration
COLREGS	International Regulations for Preventing Collisions at Sea
IALA	International Association of Marine Aids to Navigation and Light Authorities
TSS	Traffic Separation System
VHF	Very High Frequency
DSC	Digital Selective Calling
IMO	International Maritime Organization
MSC	Maritime Safety Committee
SOLAS	Convention on the Safety of Life at Sea
ARPA	Automatic Radar Plotting Aid
ECDIS	Electronic Chart Display and Information System
IEA	International Energy Agency

Chapter 1

Introduction

1.1 Background

The western countries which originated from marine civilization paid much attention to the ocean. Cicero, an ancient Rome philosopher, said more than 2000 years ago, "*who controls the ocean, who controls the world*". In the late nineteenth century, Captain Mahan of the United States proposed the rise and fall of all nations was determined by a similar view of maritime control in "*Sea Power Theory*" (Mahan, 1890). These illustrate the extraordinary importance of the oceans in some countries and in some people's minds.

At present, ocean freight has become the most important mode of transportation in international logistics. More than 2/3 of the total volume of international trade is transported by sea, while about 90% of China's total import and export goods are transported by sea; according to the 2005 CIA World Factbook, the total number of merchant ships of at least 1,000 gross register tons in the world was 30,936. In 2010, it was 38,988, an increase of 26% (CIA, 2010). On the other hand, as another main component of marine control, more and more attention has been paid by all countries to the ocean engineering. Especially since the latter half of the twentieth century, the world's population and economy have expanded rapidly, and the demand for energy and residence has also increased dramatically, which has greatly moved the development of ocean engineering.

There are lots of maritime casualties between construction ship or facilities and commercial ship, especially for the ocean engineering implemented in a port or channel. It is a big task to minimize the impact of ocean engineering on navigation safety.

1.2 Current Research

1.2.1 Current Research Abroad

The assessment of marine traffic is the main direction for the study of this topic and it is the essential part which could be used to calculate the degree of impact caused by ocean engineering.

Foreign experts and scholars do a lot of work on navigation safety assessment and evaluation, especially Japanese maritime experts, they use the marine traffic flow simulation, ship simulator simulation in marine traffic engineering to make a more reasonable and practical methods and suggestions, which are in the leading position in the world. For example, Kobayashi Hiroa put forward the evaluation of the navigation safety by evaluating the difficulty of the shipping operation (Kobayashi Hiroa, 1992); Nii Yasuo quantitatively analyzed the ship environmental factors which can influence the ship maneuvering (Nii Yasuo, 1992); Inoue Kinmi presented the possibility of the ship's encounter with the vessel during its voyage in special water area (Inoue Kinmi, 1992).

Experts in western countries have also done a lot of research in this field, such as Marine traffic simulator by Netherlands organization for Applied Scientific Research (TNO) and port navigation safety management system based on risk degree by British scholars Vldimierm Trbojevic and Barryj Carr.

1.2.2 Current domestic Research

Domestic research in this area started later than developed countries such as European countries and America, Japan and so on, but our experts and scholars have also done a lot of research on the safety assessment of navigation. Professor Wu Zhaolin of Dalian Maritime University discussed the degree of ship traffic risk from the point of view of human, ship and environment (Wu Zhaolin, 1993); In the article "*Fuzzy comprehensive evaluation method of marine traffic risk*", Zhao Renyu proposed a multi-level fuzzy comprehensive evaluation method for marine traffic risk based on accident statistics (Zhao Renyu, 1997, pp.247-251).

With the rapid development of China, the construction of infrastructure, such as wharf, waterway, breakwater, anchorage is increasing. Xiao Yangchun put forward the method of safety management for construction ship from the point of SMS of company; Wang Feilong and Li Yabing presented a comprehensive analysis of safety problems from ocean engineering and related solutions.

1.3 Main Study of This Article

1) To find and determine the impact of ocean engineering on the safety of navigation through the domestic and foreign literature research as well as specific case analysis.

2) Based on the collected data, the IWARP model is used to evaluate the marine traffic in the surrounding waters of ocean engineering, and calculate the collision probability;

3) Discuss the application and effect of AIS system in ocean engineering.

The research of this article is practical and has the value and possibility of further study. Due to some shortcomings of personal knowledge, the model and algorithm are likely to be incomplete. The author hopes this research could be helpful to the related study.

Chapter 2

Marine Traffic

2.1 Summary

As mentioned above, ocean engineering will have an impact on marine traffic, thus endangering the safety of navigation. Navigation safety is one of the final purposes of marine traffic study, it means there are no hidden dangers in the navigation environment (except shipping conditions); no threat, no damage and loss for navigation elements; the risk of damage for property and environment is controlled under the level which could be accepted. This chapter would introduce marine traffic, and points out some factors related to navigation safety.

Marine traffic has a long history, even before the railway and highway transportation. In primitive society people have learned to use the raft or canoe to transport goods, along with the increasing development of sea freight, and frequent maritime accidents, marine traffic research has gradually become one of the focus of the project to ensure the safety of navigation. Since its emergence, study on marine traffic has two main directions of research to ensure the navigation safety, one is to study and formulate regulations for preventing collisions at sea, to avoid or reduce the vessel collision risk; another is recommended to develop offshore transport routes, reduce or avoid collision between ships or between ships and obstacles (icebergs, reefs and wrecks etc.).

The subject of marine traffic engineering appeared for the first time in the 1930s, but its definition has not been fixed. Holland's famous scholar Wepster engaged in the study of marine traffic defined it as “combination of individual ship movement in a specified area” (Wepster. A, 1978, pp.348-356), which is widely used in Europe.

Scholars from different countries have different views, but there are several similarities between different views:

1) Marine traffic engineering is a branch of Engineering Science;
2) Research objective of marine traffic engineering is maritime traffic;
3) Maritime traffic engineering basically borrowed from road traffic engineering;
4) Marine traffic engineering is mainly to improve traffic safety (reduce traffic accidents) and improve traffic efficiency (prevent traffic jam) (Wu Zhaoling, 1993).

As the world's first systematic work on marine traffic engineering, Japanese scholar Fujii holds that the study should be based on the result of marine traffic investigation, and make a quantitative statement. He also put forward the research scope of marine traffic engineering is as follows:

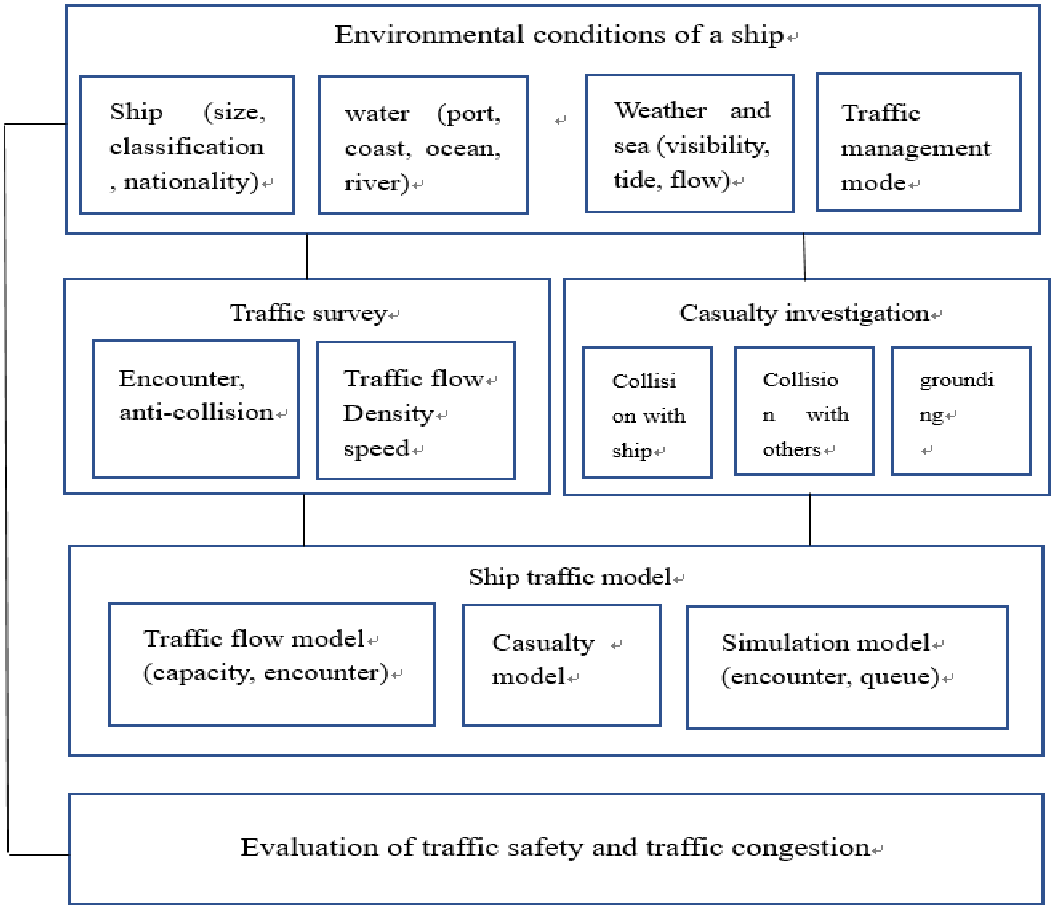


Figure 1 Scope of marine traffic study

(from “Marine traffic engineering”, complied by the author)

The study method of marine traffic could be generalized as:

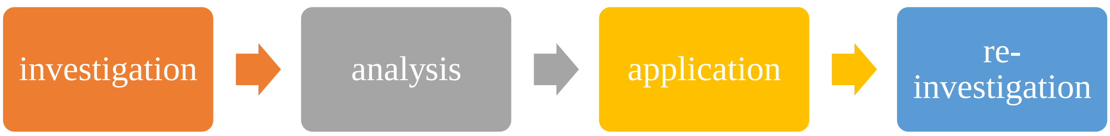


Figure 2 Method of marine traffic study

complied by the author (Wu Zhaolin, 1993)

Investigation refers to the fact to find marine traffic and maritime casualty investigation; analysis means using mathematic method to analyze the result from investigation; research findings of step 2 will be applied in traffic management and control; the last step is to discover new problem and begin another study circle.

2.2 Maritime Casualty

Maritime casualty is an unexpected, harmful or dangerous event that occurs during navigation, and an essential investigation objects of marine traffic. It usually includes collision, grounding, collision and stranding. they are usually closely related to the actual conditions of ships, the conditions of navigation and the traffic management measures (Zhang Daheng, 2007). Therefore, it is necessary to improve traffic management through the analysis and survey of maritime casualty, understand and grasp the regularity and influence factors of ship size, traffic safety, seek countermeasure, and strengthen traffic planning.

There are many factors affecting the occurrence of maritime casualty, among which ship handling factor is the most important factor. According to a study by Holland scholars, about 80% of accidents are caused by human factors (Chen Weijiong, 2002). Many scholars have also conducted a more in-depth study of ship factors and management factors. However, for any maritime casualty, there are environmental factors at that time, so it is of great significance to study the internal cause of maritime casualty by ship maneuvering environment (Ma Hui, 1998).

In this article, the author will discuss how the construction of ocean engineering affects the navigation safety, thereby increasing the risk of maritime casualty.

2.3 Navigation Environment

Generally, marine traffic engineers understand ship navigation systems from the perspective of large systems of man, ship and environment (Wu Zhaolin, 1993). Ship navigation system is a complex system composed of many factors. It affects the ship movement and the ship behavior around the human and the ship and the environment condition. In the system consisting of man, ship and environment, the ship operator is the subject of the action, the ship is the object, the environment is the influencing factor of the ship behavior and the result, and the environment has the unique position to the behavior and the result (Wen Zongyue, 2007).

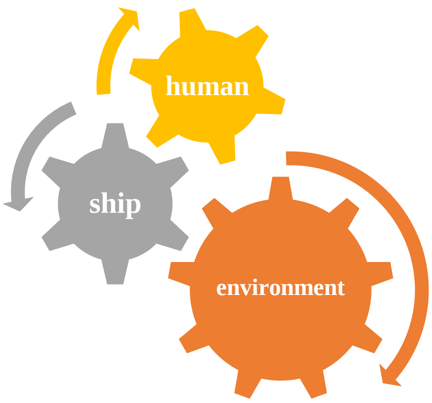


Figure 3 Structure of navigation system

(compiled by the author)

The navigation environment is an objective external environment for ships to navigate safely. The navigation environment has great influence on the traffic safety of ships. It refers to the conditions for ships, and facilities, including the influence of water surface, underwater, water and coast on the safety of marine traffic. The navigation environment can be understood as the complex ship dependence on the implementation of the specific traffic behavior of traffic in the objective world and all kinds of social relations, and it is the general term for a variety of natural factors and social factors affecting the ship's traffic activity; from the point of objective aspect, the navigation the environment has natural and social attribute. Its natural attribute is a navigation environment on ship traffic behavior when including the objective material world, namely specific navigation conditions of nature formed factors, which consists of 11 elements, the average length and breadth: channel and channel width ratio, flow, visibility, wind, traffic volume, traffic density, the number of points and cross points to the degree of VTS, traffic management and navigational aids (Zheng Zhongyi, 2006); the social attribute refers to a ship navigation environment containing specific behavior activities on all kinds of social relations, from the navigation order factors to specific performance. The navigation environment mainly manifests in the navigation condition factor and the navigation order factor.

In this paper, we mainly focus on the natural factors of navigation environment, such as the higher traffic density caused by the construction ships of ocean engineering.

Chapter 3

Ocean Engineering

3.1 History and Definition

Ocean engineering refers to the development, utilization, protection and restoration of marine resources for the purpose, and the main part of the project is in the coastline to the sea side of the new construction, reconstruction and expansion projects. It is generally believed that the main content of ocean engineering can be divided into resource development technology and equipment technology of two parts, including: land reclamation, sea embankment engineering, artificial island, sea and seabed material storage facilities, cross sea bridge, tunnel engineering, submarine pipeline and seabed electric (optical) cable engineering, marine mineral resources exploration and development and its affiliated engineering, offshore tidal power plant, power plant, power plant thermal wave ocean energy utilization project, large-scale Mari culture, artificial reef project, salt pans, desalination and other water utilization projects, marine entertainment and sports, as well as the development of landscape engineering.

Ocean engineering began with coastal engineering services for the development of coastal zones. Mediterranean countries have started sailing and building port in 1000 BC; China began the construction of the port in the coastal area in 306 to 200 BC, and began the construction of coastal protection engineering in the southeast coastal in Eastern Han Dynasty (AD 25 to 220); Holland also began to build the sea, as well as the sea and coastal reclamation in the early Middle Ages. For a long time, along with the development of marine industry and the growth of production and construction, coastal engineering has been greatly developed, its main contents include coastal protection engineering and reclamation engineering, harbor engineering, marine engineering, estuary dredging, coastal fisheries engineering and environmental protection engineering. But the term "coastal engineering" emerged until 1950s for the first time, with the marine engineering hydrology, coastal dynamics and coastal dynamic geomorphology and other related disciplines and the development of coastal engineering technology has gradually formed a discipline system.

Since the latter half of the twentieth century, the world's population and economy have expanded rapidly, and the demand for protein and energy has also increased dramatically. With the exploitation of oil and gas resources in the continental shelf, as well as the expansion and utilization of marine resources, the offshore engineering has become one of the fastest growing projects in the past 30 years. Its main symbol is the emergence of drilling and exploitation of oil (gas) offshore platform, the scope of operation has been from the depth of water within 10 meters of coastal waters extended to the depth of 300 meters of continental shelf waters.

Recently, ocean diving technology has also developed rapidly, which has been able to saturation diving, loaded submersible, diving depth of more than 10,000 meters, there have been diving operations of marine robots. In this way, from the development of offshore seabed mining to deeper waters, is now able to drill in water depth of 1000 meters of sea oil drilling in water depth of 6,000 meters of the ocean floor, in the depth of 4,000 meters of the acquisition of manganese nodules. The continental shelf waters offshore engineering (or offshore engineering) and deep-water sea projects have been far beyond the scope of coastal engineering, the application of basic science and engineering technology beyond the traditional coastal engineering category, thus forming a new subject named “ocean engineering”.

3.2 Classification

The term "ocean engineering" was first put forward in the 1960s, and its content has been gradually enriched and developed with the exploitation of marine, oil and natural gas in the past thirty years. According to the sea area, ocean engineering can be divided into coastal engineering, offshore engineering and deep-water offshore engineering, but the three are overlapped.

3.2.1 Coastal Engineering

Coastal Engineering has been given much attention since ancient times. It mainly includes coastal protection project, sea crossing project, seaport project, estuary harnessing project, dredging project at sea, coastal fishery facilities project and environmental protection facilities project.

One of the most representative coastal engineering is Dutch reclamation engineering, someone called Delta Polder Works in the Netherlands. Holland is a low latitude country, with about 1/4 of land below sea level. Because of the population density, increasing the land area has been the main policy of the country. Reclamation has a long history in Holland. At present, Holland has two reclamation engineering: Zuider

Zee works and Delta works.

In 1918, Holland's parliament passed Zuider Zee works proposed by C. Riley, and began the construction of the project in 1920. The project is a large tide retaining and reclamation project, which mainly includes the dam and 5 reclamation areas. River levee crest is 32.5 Km long, the average width of 90 meters, with 4 lane highway, a total of 38 million 500 thousand cubic meters of soil stone embankment. There are 5 sluice gates with 5 holes, each of the 600t and 200t locks. Zuider Zee and sea are separated by dams and the lake became a freshwater lake through desalination. The lake is called Ijsselmeer, and the lake depression is divided into 5 reclamation zones and is developed in stages (Hubert. N, 1982).

Although there is some debate between nation-building and the struggle against water (Ben de Pater, 2011), the project shortened the embankment line by 45km, improved irrigation and drainage conditions, and prevented salinization of land. Zuider Zee dam has become a highway connected with northeast and northwest Holland; the original river shipping was developing rapidly; Ijsselmeer can provide fresh water, promote the development of industry and agriculture and aquaculture; tourism could also be developed with the utilization of water. About 3,143,000 people have moved to the four reclamation areas, forming a prosperous economic zone.

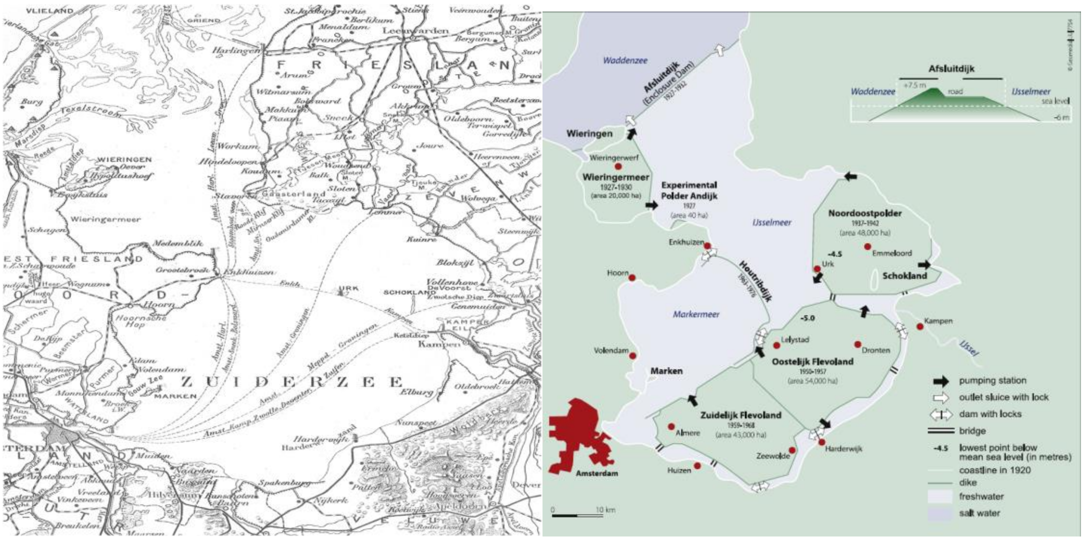


Figure 4 The difference of Zuider Zee before and after the works

(from Royal Dutch, Geographical Society)

South Holland is located in the delta of Rhine, Maas and Scheldt River, has a developed economy, dense population, and a world-famous port, Rotterdam. But because of low-lying and river fork crisscrossing, it is easy to damp disaster. It suffered a major loss in the 1953 surge in the area, causing a total of about 200,000 hectares of flooded land. Nearly 2,000 people were killed. In 1958, the Holland Congress approved the governance plan proposed by the delta Commission and began the Delta works.

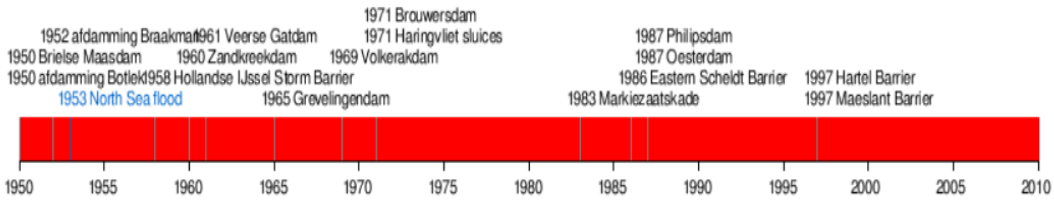


Figure 5 Time line of Delta works

(from Wikipedia)

Figure 6 Delta area of Netherlands

(from V&W)

This works shortened embankment line more than 700 km and improved the security and proof standard, so that control and management of the delta channel became more effective. It also could prevent saltwater intrusion, improve water quality and reduce sediment deposition, which made more reasonable utilization of water resources, and protected ecological environment. In addition, to fight against the anticipated effects of global warming for the next 190 years, in September 2008, the Delta commission said the country must plan for a rise of 1.3 meters in the North Sea by 2100 and 4 meters by 2200 (New York Times, 2008).

3.2.2 Offshore Engineering

Since the middle of the twentieth century, offshore engineering has been developing very fast. Mainly in the construction of the shallow waters of the continental shelf offshore platform, artificial island, and the continental shelf in the deep waters of the construction projects, such as the floating type platform, mobile semi-submersible platform (mobile semi-submersible unit) and jack up platform (self-elevating unit), oil and gas, floating platform floating type oil storage, oil refineries, floating airport construction project etc.

The most well-known offshore engineering is drilling platform; to some extent, the development of offshore engineering could be mainly described as the development of drilling platform.

Period	**Stage**
1887-1947	Germination stage
1947-1959	Expansion stage
1959-1973	Professional and international stage
1973-1985	technological innovation stage
1985-1995	Reflective stage
1995 until now	mature stage

Table 1 Time table of the development of drilling platform

(compiled by the author)

Drilling platform is used to exploit the oil and gas undersea. Oil and gas are the most widely used and important energy for human, and the demand is increasing fast. Marine oil and gas resources are abundant. It is estimated that the oil and gas production would be up to 800 to 900 million tons, accounting for 30% of the world's total output.

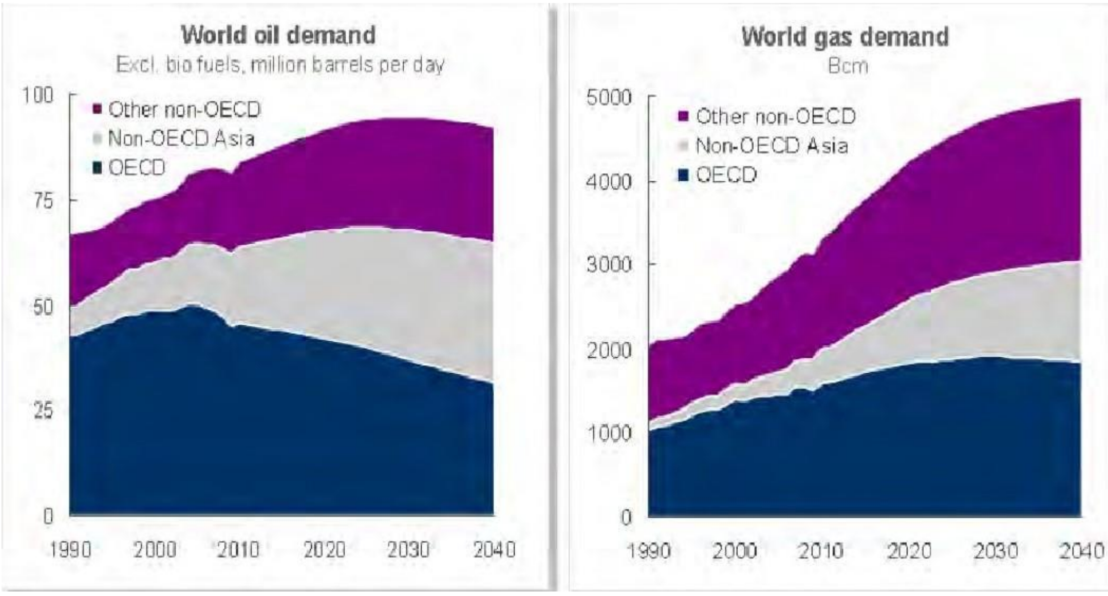


Figure 7 World oil demand and gas demand

(from IEA)

In 1897, at the United States California Summer land tide zone beach, a 76.2-meter-long wooden frame was set up, and the rig on top of wells is the world's first offshore drilling platform. After more than a century's development, experiencing several serious accidents, such as Piper Alpha disaster which caused 167 deaths, drilling platform technology has been increasingly improved. Several months ago, the world's largest drilling platform “BLUE WHALE” was completed in China and put into use, it also marks the birth of the seventh-generation drilling platform.

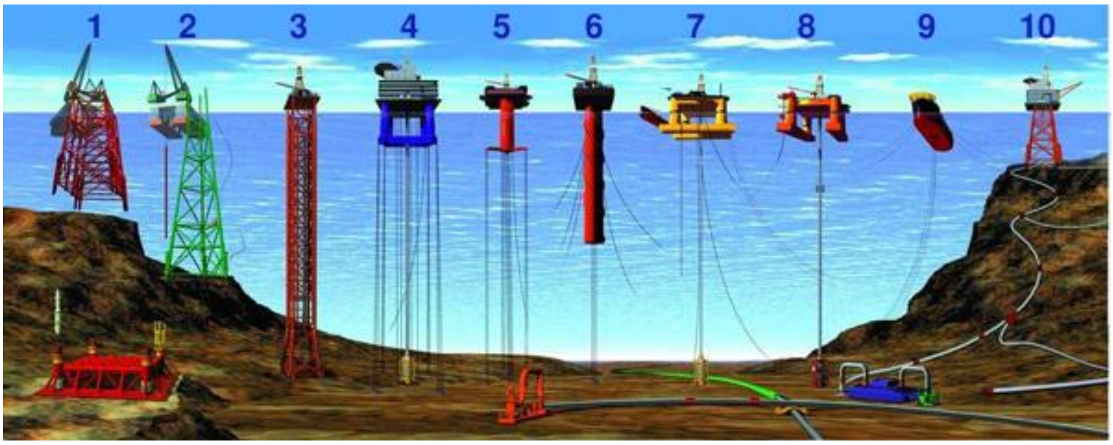


Figure 8 Different types of drilling platforms

1, 2) conventional fixed platforms; 3) compliant tower; 4, 5) vertically moored tension leg and mini-tension leg platform; 6) spar; 7, 8) semi-submersibles; 9) floating production, storage, and offloading facility; 10) sub-sea completion and tie-back to host facility

(from NOAA, 2008)

3.2.3 Deep-water Offshore Engineering

Deep-water offshore engineering includes unmanned diving submersible and remote seabed mining facilities and other construction projects.

Submersible is a small vehicle designed to operate underwater. There are many types of submersibles, including both crewed and no crewed craft, otherwise known as remotely operated vehicles or ROVs (The Canadian Encyclopedia, 2011). Submersibles have many uses worldwide, such as oceanography, underwater archaeology, ocean exploration, adventure, equipment maintenance and recovery, and underwater videography (Erik Seedhouse, 2010). Unmanned submersibles called "marine remotely operated vehicles" or MROVs are widely used today to work in water too deep or too dangerous for divers.

Undersea mining has a long history, for example, the United Kingdom began undersea mining since 1620; but the feature of seabed mining was small-scale, narrow range, offshore before the 1960s. Since the 1960s, people have paid more attention to it, especially the development of submarine oil and gas, and the development of deep-sea manganese nodules and hydrothermal deposits has also developed rapidly. At present, the world mining from the seabed mineral production in oil and natural gas accounted for more than 90%, the total output value followed by coal accounting for 3 ~ 5%, gravel and heavy placer accounting for about 2%. China is currently mining the seafloor, using construction of the gravel and ilmenite, zircon, monazite and xenotime placer ore and oil and gas, but also has a certain number of manganese nodules from the bottom of the Pacific Ocean.

3.3 Environmental Issue

It should be noted that except the study between marine traffic, the environmental issue is the most important topic for ocean engineering.

Environmental protection has been a most concerned problem, ocean engineering is equally inevitable. Petroleum resource development has direct impact on marine environment (Xie Zhiyuan, 2017). Drilling platform is the basic unit of Petroleum resource development, and one of the important sources of pollution. The main pollutants produced by the platform are petroleum, chemical additives, engineering waste and industrial sewage, etc. There are two main impacts on the marine environment, the toxicity of pollutants can cause massive deaths of marine life; on the other hand, pollutants will destroy the balance of the ocean, affect the photosynthesis of marine plants, which may cause red tides and destruction of fishery resources.

Coastal engineering can also cause marine pollution, and even worse than drilling platform, which could be manifested in the following aspects:

1) coastal engineering affects marine water quality;

2) coastal engineering affects the oceanic hydrology and hydrodynamics conditions;

3) coastal engineering affects the offshore fisheries.

Take dredging for example, the environmental impact of dredging includes an increase in the level of turbidity, organic and metal compounds in the water and dredged sediment. (Wu. G, 2007).

Chapter 4

Analysis of Influence

Last chapter mentioned three types of ocean engineering, offshore engineering and deep-water offshore engineering are far from the dense water area, such as port and waterway, and there are fewer construction ships. Except for the extreme reasons such as poor visibility, poor observation and radar fault at the same time, the navigation safety impacts on the surrounding waters can be neglected. Thus, in this chapter, the influence caused by coastal engineering will be discussed.

Taking Tianjin port as an example, since the second half of 2008, especially from 2009 to 2011, major construction project in Tianjin port started intensively, including dredging project, port construction project, fishing project, etc. As of April 2011, Tianjin port has more than 10 construction companies, and more than 20 coastal engineering, more than 600 construction ships, including inland ship construction, sand transport ship reached more than 400, accounting for 66.7% of the total construction of the ship, they seriously affect the navigation safety of Tianjin port (Kong Xianwei, 2013). The influences could be generalized as follows (Wang Feilong, 2014):

First, increase traffic flow, which is the most prominent problem. The frequent entry and exit of construction waters by construction ships will inevitably increase the vessel traffic flow in waters, the ship navigation density and the frequency of vessel collision avoidance.

Second, occupy navigable waters. For example, in the construction of waterway dredging, to ensure the production efficiency of the port, the unilateral construction method of " navigation and construction together" is generally adopted. Construction ships need to occupy a certain channel width, so that the navigable waters of ships can be reduced. The construction of the ship's emergency shelter will also occupy a certain anchorage resources.

Third, affect visual lookout. The visibility at night or in fog and other adverse conditions, the construction of ships without the provisions of the display lights, shapes, it is easy to induce ships out of fairway or into construction waters. The strong lights at night construction will also interfere with the driver's lookout.

Fourth, reduce the navigable depth of waters. In the process of throwing mud, blasting, etc., if the construction ship failed to throw water in designated waters or failed to remove the obstructions and debris in time, it will cause partial navigation and shallow water depth.

Fifth, damage to submarine pipelines. In the water area with submarine light cables or pipelines, if the construction ship breaks down at random or carries out dredging and blasting near the pipeline, it will lead to accidents such as pipeline damage and pollution.

Sixth, cause safety accident. The construction of ship condition, maneuverability, crew seamanship, management level is uneven, the rental ship navigation environment of general construction waters is not familiar, part of the construction of a ship is often not in accordance with the provisions of sea route, they crossed the fairway and anchorage, berthing area, causing big security risk. If the construction ship overload, unbalanced load, in case of storm jet, it is easy to cause the ship sinking or rollover (Li Yan, 2007).

The author will give a more concrete example to express the impact of ocean engineering on navigation safety.

4.1 QIAN HAI Bay Dredging Project

Dredging, as one type of coastal engineering, has multiple uses, including aiding ship navigation and expanding ports and harbors (Norpadzlihatun Manap, 2016). Many dredging projects are under construction, among which, Panama Canal project is the most well-known (Schexnayder, 2010). Majority of dredging projects are taking place in developing countries, such as India and Malaysia, and this may due to the rise of maritime trade in these countries (Norpadzlihatun Manap, 2014). For China, as a developing country, there are also lots of dredging projects undertaken, aiming to broaden the channel for ports or improve the residential environment for the people who live near the seashore. Qian Hai Bay dredging project is one of the largest scale dredging projects in South China Sea as the author is engaged in China MSA. In the following part, the influence would be analyzed qualitatively through this concrete example, which is under construction in the jurisdiction of China MSA.

4.1.1 Geographical Position

Qian Hai Bay dredging project is aimed to improve the residential environment, and create a better navigation environment for surround ports. Qian Hai Bay is located on the west She Kou Peninsula in Shenzhen. It is on the East Zhu Jiang River Estuary, adjacent to Hong Kong and Macao, covering an area of 14.92 square kilometers.

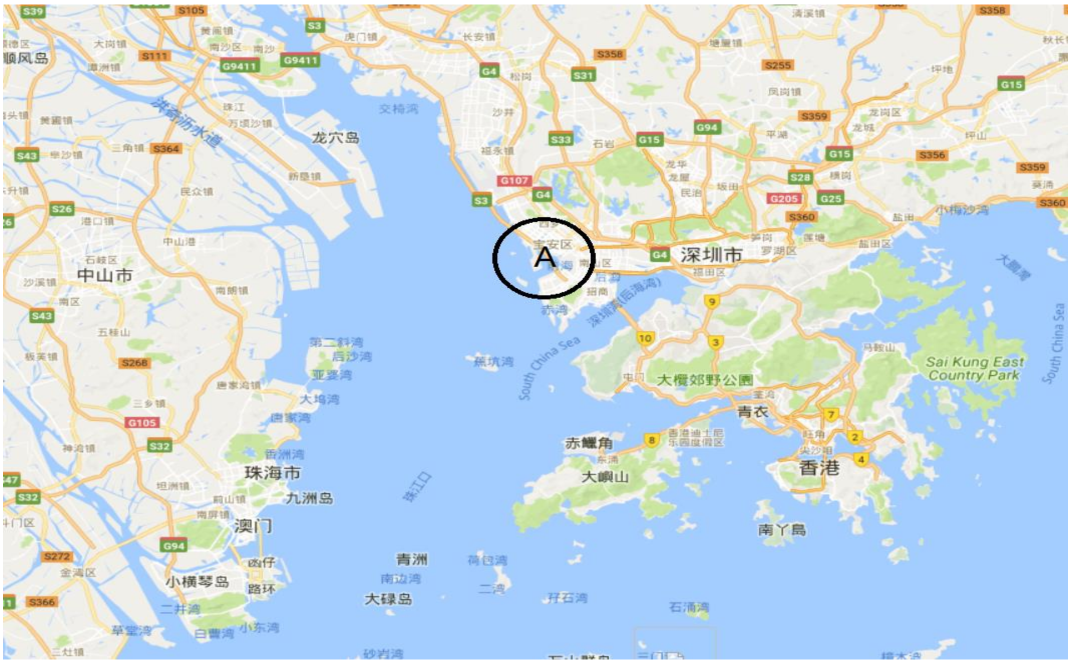


Figure 9 Geographical position of Qian Hai Bay, A stand for Qian Hai Bay

(from google map)

In addition, Qian Hai Bay is surrounded by two ports, Da Chan Bay port and She Kou port. Da Chan Bay port covers an area of 112 hectares with 5 berths along its quayside of 1,830 meters and 600 meters wide. Alongside depth is initially -15.5 meters, which can handle the world’s largest existing and planned container vessels. She Kou port is one of the most important comprehensive ports in China, the annual throughput capacity is 15 million tons, and the annual container throughput capacity is 500 thousand TEUs, and the annual passenger throughput capacity is 5 million.

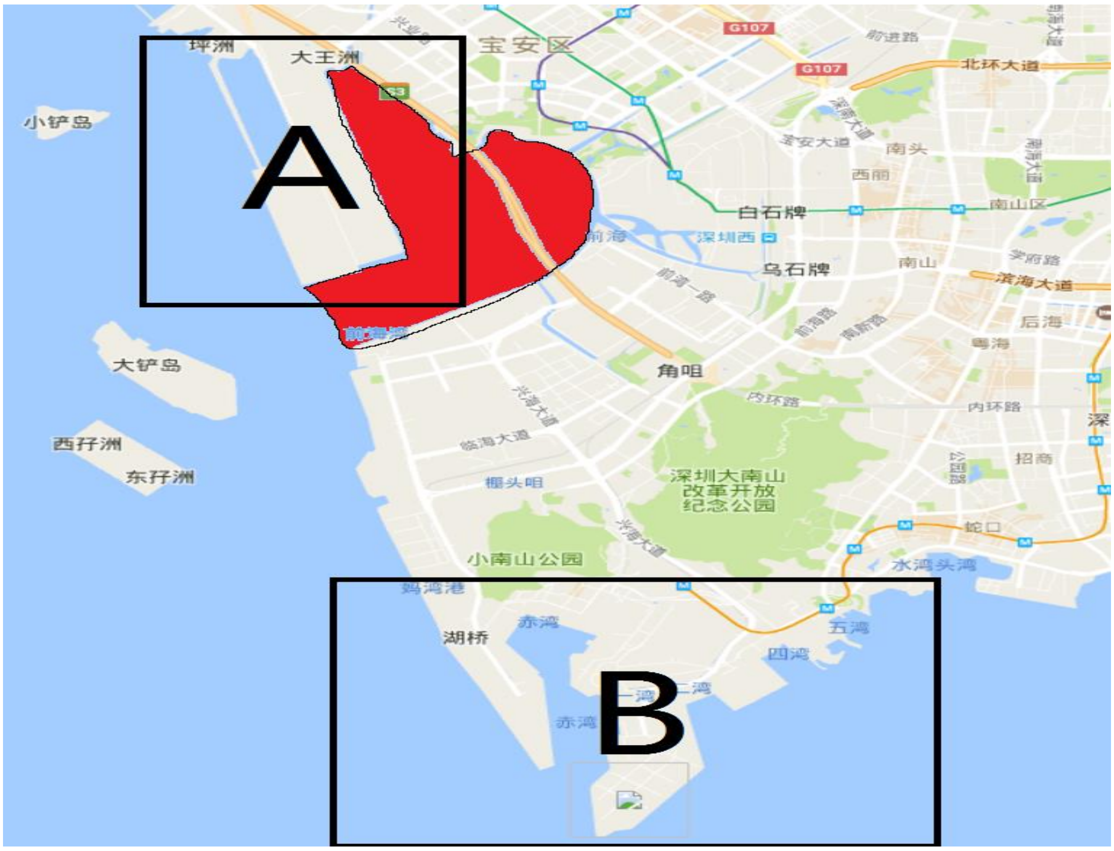


Figure 10 Surround ports of Qian Hai Bay (The red zone), A is Da Chan Bay port, B is She Kou port

(from google map, and complied by the author)

4.1.2 Summary

The dredging project focuses on the silt of Qian Hai Bay, which is about 5 million 400 thousand square meters, and planed dredging to the depth of -2.0m; ensure the beach do not exposed during the low tide after the implementation, form a reasonable layout of beach groove, and eliminate Qian Hai Bay endogenous pollution.

The dredged soil in the dredging area of this project is mainly composed of silt, with a project capacity of about 11,259,000 cubic meters, with a net dredging capacity of about 10,269,000 meters, and a total of 990, 600 cubic meters of back silting during construction.

The construction vessels consist of grab dredgers, backhoe dredges and sludge boats. The basic construction technique is:

Figure 11 Basic process of Qian Hai Bay dredging project

(compiled by the author)

The designated mud dumping area is Huang Mao Island, which is 70 kilometers far from the project area. This work began in 2015, and will finish in 2017.

4.1.3 Influence

As the main project area is in the Qian Hai Bay, where has no commercial channel; therefore, the dredging project has no influence on the navigation safety. However, the waste transfer process does.

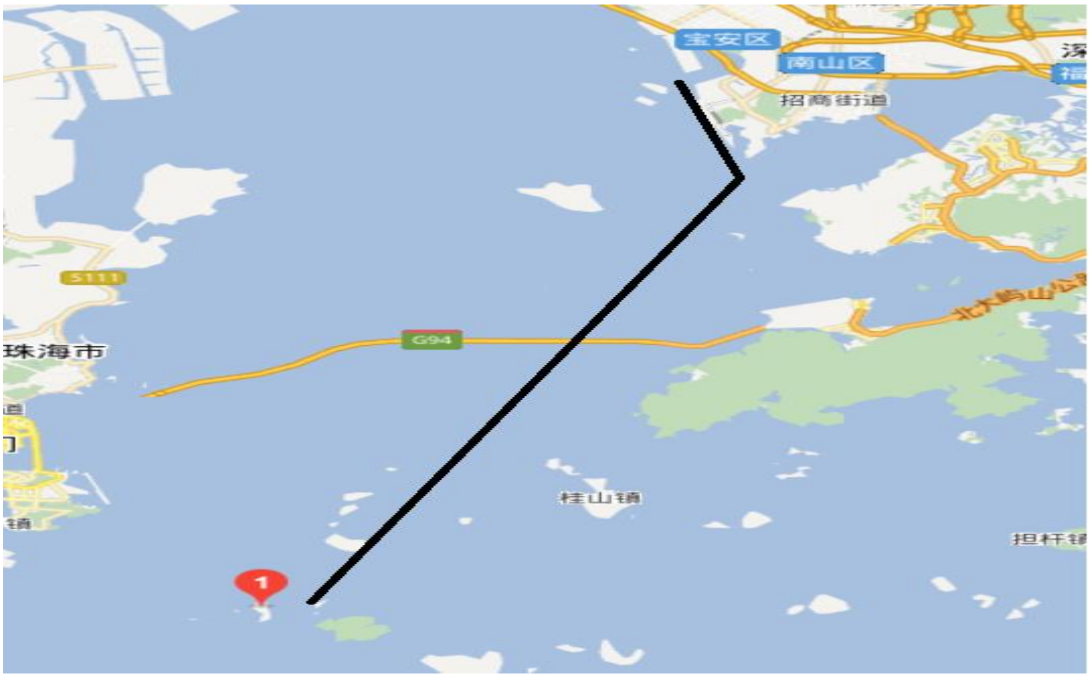


Figure 12 Designed route of sludge boat for mud dumping

(from google map, and complied by the author)

The above figure shows the designed route of sludge boat for this project. It has mentioned that Qian Hai Bay is surrounded by two important port, Da Chan Bay and She Kou, which means there are some essential channels to entry and depart the two ports; what's more, the designed route is also one of the important routes for the vessels from Zhu Jiang river to Hong Kong.

More concretely, the designed route of sludge boat for mud dumping will pass four main channels, Da Chan Bay approach channel, western public channel, Long Gu channel and Long Gu west channel.

Da Chan Bay approach channel is the only channel for container liner berthing and departing from Da Chan Bay port, and it is also one of the main channels for the vessels sailing from Zhu Jiang river to She Kou and Hong Kong.

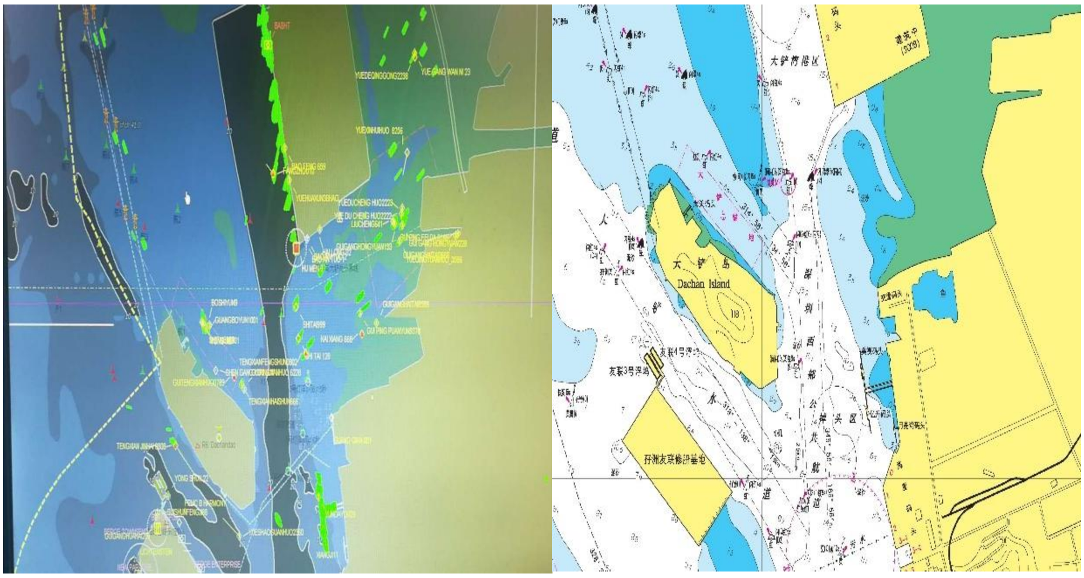


Figure 13 Da Chan Bay approach channel and its VTS screenshot

(from Shenzhen VTS)

Western public channel is the most important channel in western Shenzhen water, along this narrow channel there are several container berths and bulk carrier berths, half of the channel would be occupied by a huge container when berthing and departing. Meanwhile, there are two anchorages in the opposite side which are the only two anchorages in this area. Thousands of ships proceeding to She Kou, Hong Kong and Zhu Jiang river are using this crucial channel.

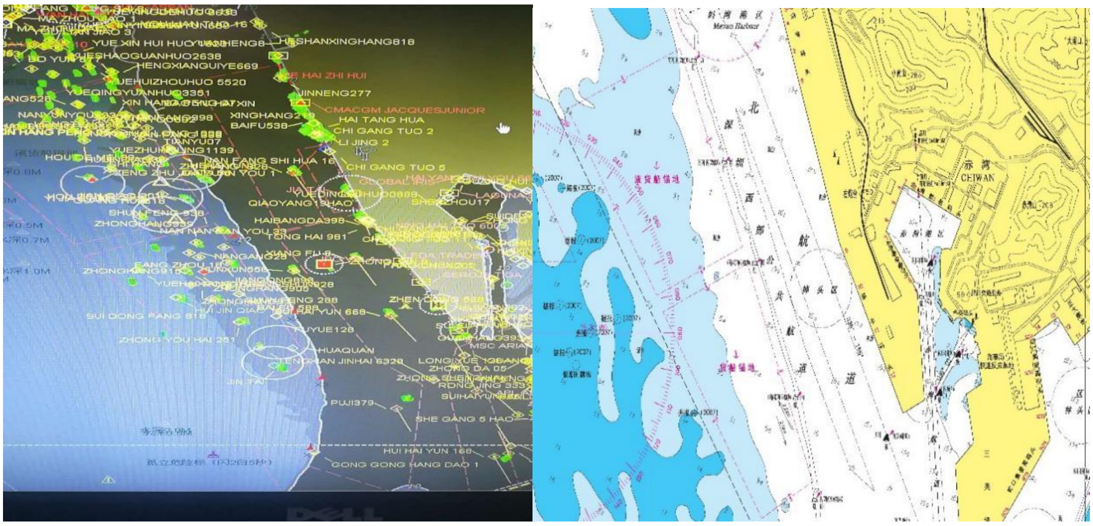


Figure 14 Western public channel and its VTS screenshot

(from Shenzhen VTS)

Long Gu channel is the main channel for vessels from Hong Kong to She Kou, especially from container liners, Shenzhen pilot boarding point is just in this channel. And there are many multi-purpose carriers sailing on this channel from oil platform in south China sea and Chi Wan base in She Kou.

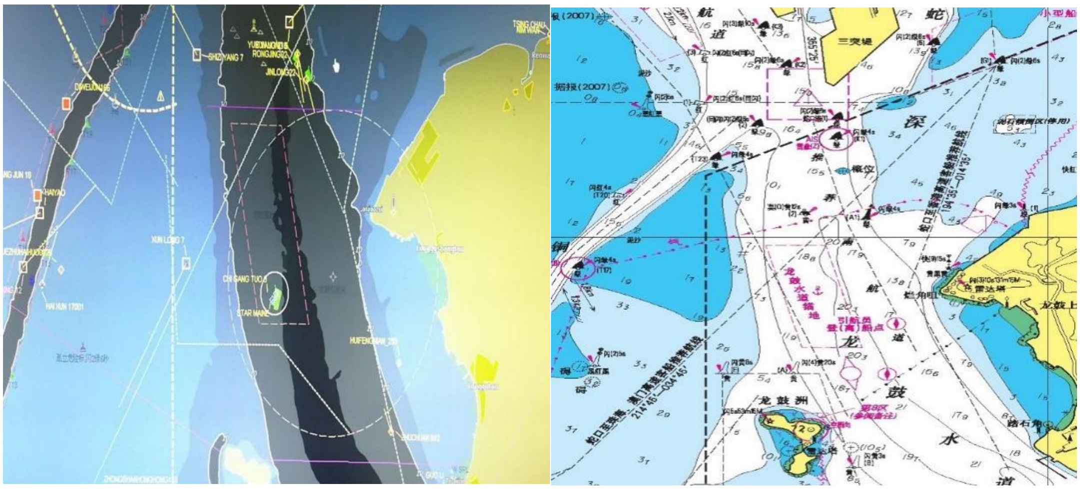


Figure 15 Long Gu channel and its VTS screenshot

(from Shenzhen VTS)

West Long Gu channel is a narrow and shallow channel for small vessels entering and leaving Shenzhen. it is easy to ground if off course or anti-collision.

Figure 16 West Long Gu channel and its VTS screenshot

(from Shenzhen VTS)

Theoretically, the sudden booming of sludge boats in Da Chan Bay approach channel would reduce work efficiency of port, greatly increasing the shipping density and leading to a higher casualty risk in west public channel and Long Gu channel, the grounding and collision accident would rise in Long Gu west channel. In addition, Da Chan Bay port has received some reports, suggesting that the light of construction area has interfered the ships to berth and depart.

However, in daily supervision of this project, we also find some other practical problems. First, to reduce the cost, some sludge boats dump the mud on the way to Huang Mao Island. What's worse, a part of the mud is thrown into the channel directly which brings a large threat for grounding. Second, no dumping the mud illegally but take the short cut to Huang Mao Island, and it also increases the risk of grounding casualty. Third, the ship conditions of sludge boats are not neat; some of the boats have a bad steerage, adding the behavior of overloading, it is difficult for them(who???) to take anti-collision steps. Fifth, majority of the sludge boats are employed temporarily, the crewmembers are unfamiliar with water conditions.

Figure 17 Ship conditions of sludge boats

(from Live shooting of Shenzhen MSA)

4.2 Quantitative Analysis of Impact

According to the above analysis, the impact of ocean engineering on marine traffic and navigation safety mainly focused on the increasing of ship density and traffic flow if the ocean engineering is not located in the channel, which may lead to a higher possibility of maritime casualty, especially for collision accident. Thus, to some extent, quantitative analysis is a research on the ship collision possibility in the surrounding water of ocean engineering.

According to the research of Fujii, the collision casualty possibility of ship F consists of Na (Geometric probability of ship casualty) and Pc (Causation factors), that is

(Fujii. Y, 1983, pp.91-98):

$$F = Na \times Pc$$

The causation factors are the reduction factor, which means that the ship is on the course of stranding and collision, and there is no probability of accident due to the operation. Causation factors are functions of visibility, wind, flow, and ship density. The causation factors are related to many parameters: traffic flow, collision avoidance, weather conditions, ship handling performance, and so on.

Jutta Ylitalo summarized and arranged the previous study of causation factors (Jutta Ylitalo, 2009). The causation factors ranged from $6.83*10^{-5}$ to $5.8*10^{-4}$.

4.2.1 Classification of Maritime Collision Casualty

According to COLREGS, if not considering the type of ship, only concern the relative position between the two vessels, the encounter situation is divided into three cases, respectively, Head-on, Overtaking and Crossing (Sun Wenqiang, 2006).

Head-on refers to two ships sailing along the channel in a straight line or nearly opposite nearly a straight line (range heading around within 5 degrees), which may constitute a dangerous situation of collision;

Overtaking refers to the situation in which a motor vessel is catching or overtaking the vessel in a direction greater than 22.5 degrees from the cross of another motor vessel, which may constitute a collision risk;

Crossing refers to two vessels are in the cross angle within 5 degrees ~112.5 degrees, which may constitute a dangerous situation of collision, in which the traverse can be regarded as a special case of crossing.

According to the navigation behavior and encounter situation of ship, collision situations can be divided into head-on collision, overtaking collision and cross collision; in which, cross collision can be divided into merging collision, crossing collision and bend collision. Bend collision is a collision that occurs when a ship sails at a bend and is turned over (Jutta Ylitalo, 2010).

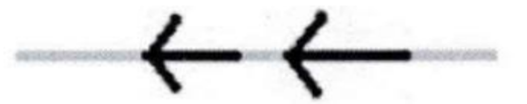
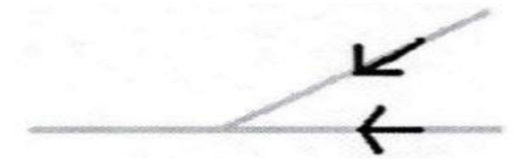
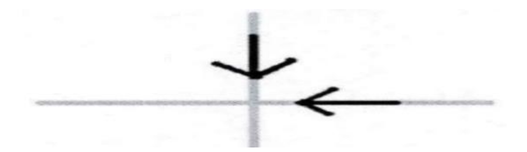
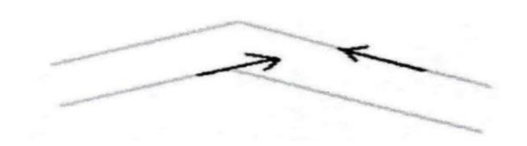
Types of collision	**Simply diagram**
Head-on collision	
Overtaking collision	
Merging collision	
Crossing collision	
Bend collision	

Table 2 Diagrams for five types of collision

(compiled by the author)

For the probability of collision casualty, there are mainly four models, Macduff model, Pedersen model, COWI model, IWRAP model.

4.2.2 Collision Probability Models

1) Macduff model

According to the theory of molecular motion, a collision model is established (Macduff, 1974, pp.144-148). The model only has collision probability of intersection. Macduff assumed that the ships on the fairway have the same speed and similar scales, and the probability P of collision in the approaching with the θ angle is:

$$p = \frac{XL}{D^2} \times \frac{\sin(\frac{\theta}{2})}{925}$$

D stands for the average distance between ships

L stands for the average length of ship

X stands for the actual distance the ship has sailed

2) Perderson model

Perderson calculated the probability for ship collision of the situation shown in figure 18 (Perderson, 1995). The collision zone is red, if the distance between the two ships collision is less than the geometric diameter, it is reasonable to believe that the two ships will collide.

In the two channels with an angle of θ, vessel i and vessel j sail at speed V_i and V_j respectively, and their relative speed is:

$$V = \sqrt{V_i^2 + V_j^2 - 2V_i V_j \cos\theta}$$

According to Perderson model, geometric collision diameter could be calculated as:

$$D = \frac{LiVj + LjVi}{V} \sin\theta + Bj\left[1 - \left(\sin\theta \frac{Vi}{V}\right)^2\right]^{\frac{1}{2}} + Bi\left[1 - \left(\sin\theta \frac{Vj}{V}\right)^2\right]^{\frac{1}{2}}$$

L and B is the length and width of the ships.

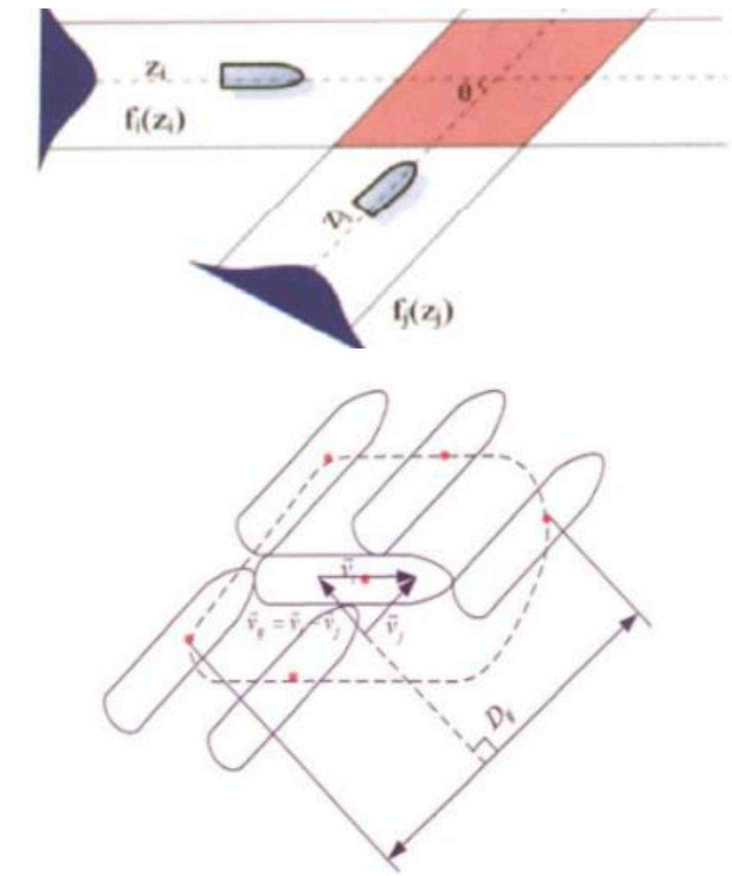


Figure 18 Collision zone and Geometric collision diameter

(from Perderson, 1995)

In the special period Δt, and the certain area dz_j, the number of vessel j which would collide with vessel i is:

$$Na_{(j)} = \frac{Q_j^{(2)}}{V_j^{(2)}} f_j^{(2)}(z_j) v_{ij} D_{ij} dz_j \Delta t$$

Usually f_j is normal or uniform distribution. When normal distribution:

$$f_j(z_j) = \frac{1}{\sigma_j\sqrt{2\pi}} exp\left\{\frac{-(z_j - \mu_j)^2}{2(\sigma_j)^2}\right\}$$

μ_j and σ_j are the mean and standard deviations of the vessel flow in the vertical direction of the channel.

When uniform distribution:

$$f_j(z_j) = \begin{cases} b - a & a \leq z_j \leq b \\ 0 & else \end{cases}$$

A and B are the upper and lower ends of channel.

In the collision zone (red zone), the number of vessel i is:

$$Na_i = \frac{Q_i^{(1)}}{V_i^{(1)}} f_i^{(1)}(z_i) dz_i$$

Thus, within the collision risk area (red zone), the number of ships that may collide is:

$$\mathrm{Na} = \sum_i \sum_j \iint_{\Omega(z_i, z_j)} \frac{Q_I^{(1)} Q_j^{(2)}}{V_i^{(1)} V_j^{(2)}} f_i^{(1)}(z_i) f_j^{(2)}(z_j) V_{ij} D_{ij} dA\Delta t$$

$Q_j^{(2)}$ stands for the number of vessel j sailing within fairway 2 in the period of Δt;

$f_j^{(2)}(z_j)$ stands for density function of the distribution of navigational trajectories of vessel j within fairway 2;

$f_i^{(1)}(z_i)$ stands for density function of the distribution of navigational trajectories of vessel i within fairway 1;

$V_j^{(2)}$ stands for the speed of vessel j is fairway 2;

$V_i^{(1)}$ stands for the speed of vessel i is fairway 1;

z_j stands for the distance of a ship from the center line of the fairway;

V_{ij} stands for the relative speed of vessel i within fairway 1 and vessel j within fairway 2;

D_{ij} stands for the geometric collision diameter of vessel i within fairway 1 and vessel j within fairway 2.

3) COWI model

Collision casualty is divided into crossing collision, head-on collision and overtaking collision by COWI (COWI, 2008).

For the collision probability of head-on collision and overtaking collision, the formulation is:

$$P_x = P_T P_G P_C K_{RR}$$

P_T stands for annual encounter probability;

P_G stands for geometric collision probability;

P_C stands for causation factor;

K_{RR} stands for risk correction value.

In which, P_T could be calculated as follows:

$$P_T = L N_1 N_2 \left|\frac{V_1 - V_2}{V_1 V_2}\right|$$

L stands for the length of channel;

$N_1 N_2$ stands for the annual traffic flow;

$V_1 V_2$ stands for the ship speed;

The risk correction value K_{RR} is not used to change the cause factor itself, but to correct the factors that affect the collision probability.

On the other hand, COWI defines cross collisions as collisions caused by sailing along different waterways. A collision may occur theoretically when two ships cross the track. The cross probabilities P_I of two tracks crossing each other (X crossing) and one route ship merging into another route (Y crossing) are 1 and 0.5 respectively.

The probability of ship collision on the cross route depends on the critical time interval Δt, and the critical time interval can be calculated by the following formula:

$$\Delta t = \frac{1}{V_1 V_2}\left[B_2\left|\frac{V_2}{\sin\theta} - \frac{V_1}{\tan\theta}\right| + B_1\left|\frac{V_1}{\sin\theta} - \frac{V_2}{\tan\theta}\right| + L_1|V_2| + L_2|V_1|\right]$$

L_1 and L_2 stands for the length of ships;

θ stands for the angle of crossing channels

The model assumes that the vessel sailing in the channel follows Poisson distribution, and the vessel geometry collision probability P_G is:

$$P_G = N_1(1 - e^{-N_2 \Delta T}) \approx N_1 N_2 \Delta t$$

The annual collision probability $P_X = P_1 P_G P_C K_{RR}$

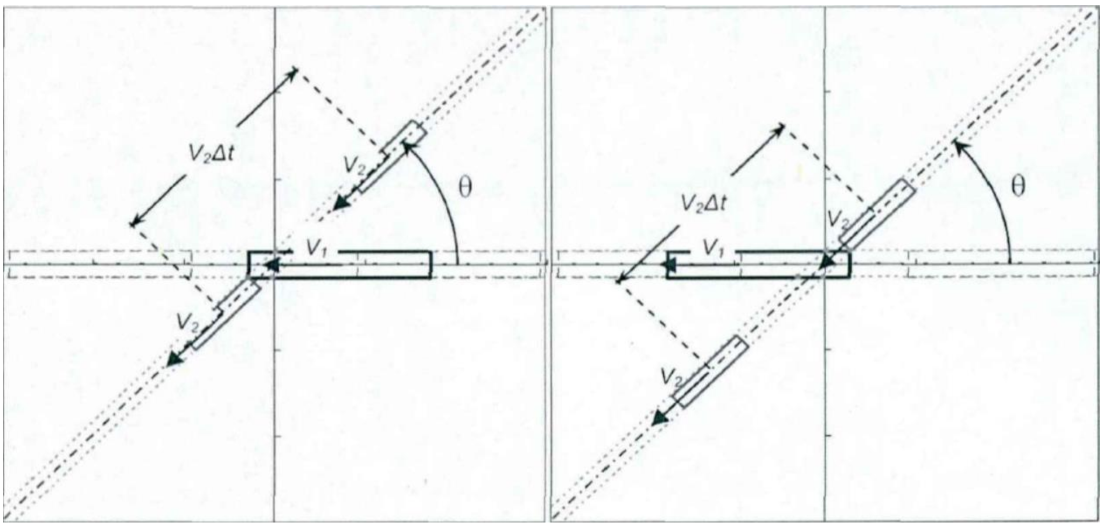


Figure 19 Diagram for the crossing encounter of COWI

(from COWI, 2008)

4.2.3 IWARP

In this study, the risk analysis model IWARP which is used by IALA is adopted, to calculate the collision risk of water area where the ocean engineering is under construction. IWARP model is based on AIS historical data, which takes the causation probability as the premise and analyzes the collision probability and the grounding probability of the ship. In view of different ship types and ship flow in different routes, the collision probability and grounding probability can be calculated, analyzed and compared by IWARP model (IALA, 2017). In addition, the probability calculated from IWARP is the result without any anti-collision measures when two ships are encountering.

According to the ship encounter situation and position, the collision of ships is classified into two categories: the collision occurred in the straight channel, including head-on collision and overtaking collision; collision occurred in the cross sector, means crossing collision.

As for the IWARP model, the corresponding data are presented (Friis, 2008).

Type of encounter	**Causation factors**
head-on	$0.5*10^{-4}$
Over-taking	$1.1*10^{-4}$
cross	$1.3*10^{-4}$
bend	$1.3*10^{-4}$
Merging	$1.3*10^{-4}$
grounding	$1.6*10^{-4}$

Table 3 Causation factor of IWARP model

(from Friis-Hansen, 2008)

1) Head-on collision

In IWARP, the head-on collision is defined as the angle of two ships between -10 degrees ~10 degrees. In the two-way channel, the expected values of each vessel's distribution function are σ_1 and σ_2 respectively, and μ is the vertical distance between the two ships.

According to IWARP, the frequency of the occurrence of the collision cause for the ship is calculated as follows:

$$N_A = L_W \sum_{i,j} P_{G_{i,j}}^{head-on} \frac{V_{ij}}{V_i V_j} (Q_i Q_j)$$

$V_i V_j$ stands for the ships speed, V_{ij} stands for relative speed which value is $(V_i + V_j)$, $Q_i Q_j$ stands for the traffic flow on both sides, $P_{G_{i,j}}^{head-on}$ is the probability of collision for the ship in head-on situation, which could be calculated by the following formula:

$$P_{G_{i,j}}^{head-on} = \mathrm{P}\left[y_i - \frac{B_i}{2} < -y_j + \frac{B_j}{2} \cap y_i + \frac{B_i}{2} > -y_j - \frac{B_j}{2}\right]$$
$$= \int_{-\infty}^{\infty} f_{Y_i}(y_i) \left[F_{Y_j}\left(-y_j + \bar{B}\right) - F_{Y_j}\left(-y_j - \bar{B}\right)\right] dy_j$$

The formula is to calculate the coincidence probability of the ship distribution curve on both sides of the fairway. f is the ship's distribution density function. B is the width of ship. If the ship distribution is a normal distribution, the upper model can be simplified as

$$P_{G_{i,j}}^{head-on} = \Phi\left(\frac{\overline{B_{ij}} - \mu_{ij}}{\sigma_{ij}}\right) - \Phi\left(-\frac{\overline{B_{ij}} + \mu_{ij}}{\sigma_{ij}}\right)$$

In which, $\sigma_{ij} = \sqrt{\sigma_i^2 + \sigma_j^2}$; $\overline{B_{ij}} = \frac{B_i+B_j}{2}$; μ_{ij} is the vertical distance between the ships.

2) Overtaking collision

In IWARP, the angle of two ships between 170 degrees~190 degrees are defined as overtaking. The collision probability of a ship overtaking is similar to that of the head-on collision. It is the only different when calculated $P_{G_{i,j}}^{overtaking}$ and μ_{ij}, and the following formula is used to calculate the overtaking collision probability:

$$P_{G_{i,j}}^{overtaking} = \mathrm{P}\left[y_i - y_j < \frac{B_i + B_j}{2}\right] - P\left[y_i - y_j < -\frac{B_i + B_j}{2}\right]$$

$$\mu_{ij} = |\mu_i - \mu_j|$$

3) Crossing collision

In IWARP model, the angle between 10 degrees ~170 degrees are defined as the crossing encounter. Geometry collision diameter and relative speed of crossing encounter are as that of Perdersen model, and calculation formula of ships collision inducement frequency $N_G^{crossing}$ is as follows:

$$N_G^{crossing} = \sum_{i,j} \frac{Q_i Q_j}{V_i V_j} D_{ij} V_{ij} \frac{1}{\sin\theta}$$

Q_i and Q_j stand for the specific vessel traffic flow per unit time in the cross channel;

V_i and V_j stand for the speed of a ship in a cross channel;

V_{ij} stands for the relative speed;

D_{ij} stands for the collision zone diameter without any action to avoid collision conditions;

θ stands for channel crossing angle.

4.3 Collision Risk in Qian Hai Bay Dredging Project

According to the introduce of Qian Hai Dredging Project in the above content, the main change is the increase of traffic flow and density result from the sludge boats. In this part, calculate the previous and later collision probability when the sludge boat appeared. Through the comparison of two collision probabilities, the influence of Qian Hai Bay dredging Project could be quantitative calculated.

As TSS is adopted in western Shenzhen waters, the collision risk of head-on is neglected. Therefore, the two collision zones related to sludge boats are in the intersection of Long Gu channel and Wester public channel, Da Chan Bay approach channel and the temporary channel for entrance and exit construction area, which are shown in Figure 20 (black circles).

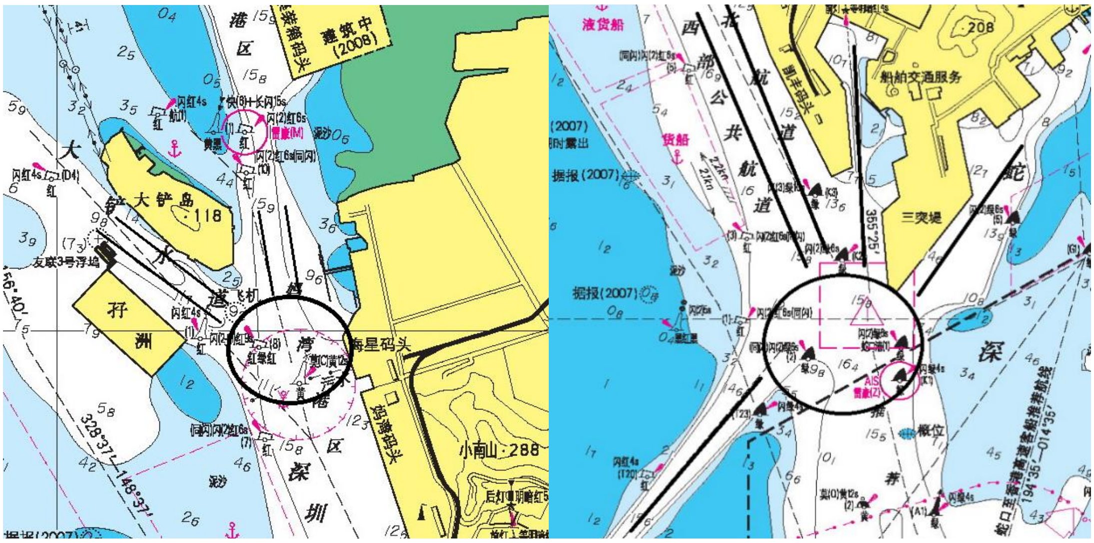


Figure 20 Encounter points of Qian Hai dredging project

(compiled by the author)

From the statistics of Shenzhen Maritime Safety Administration, the ships in Long Gu channel mainly focused on four types: container liners, small container barge, general cargo ship and multi-purpose ships; meanwhile, the type of ships in western public channel and Da Chan Bay approach channel is container liner, small container barge and general cargo ship; the temporary channel for entrance and exit construction area is only used for construction ships. Majority of container liners in the water area are 250-300 meters, small container barges and general cargo ships are 50-75 meters and multi-purpose ships are almost 75 meters. Thus, the behalves of ship types in this calculation are as follows:

Ship types	**Length/m**	**Width/m**	**Average speed/nm**
Container liner	250	30	10
Container barge	70	14	6
General cargo ship	60	12	6
Multi-purpose ship	75	15	8

Table 4 Behalves of the ships in the water area

(Compiled by the author)

On the other hand, the behavior of sludge boat could be defined as:

Ship type	**Length/m**	**Width/m**	**Average speed/nm**
Sludge boat	50	11	6

Table 5 The index of behave for sludge boat

(compiled by the author)

Before the construction of Qian Hai Bay Dredging Project, there is no construction ship or sludge boat using the temporary channel, and no collision risk exists in the intersection of Da Chan Bay approach channel and the temporary channel. The data of traffic flow per day in Long Gu channel and Western public channel from Shenzhen MSA Navigation Management Department is (ships which is less than 50m are ignored here, such as fish boat and tug):

	Long Gu channel	**Western public channel**
Container liner	15	12
Container barge	187	158
General cargo ship	48	44
Multi-purpose ship	4	0
total	254	214

Table 6 Traffic flow in Long Gu channel and Western public channel

(from Shenzhen MSA Navigation management department)

The collision probability F_b could be calculated according to IWARP model by following formulations:

$$\mathrm{F}_b = N_G^{crossing} \times \mathrm{Pc}$$

$$N_G^{crossing} = \sum_{i,j} \frac{Q_i Q_j}{V_i V_j} D_{ij} V_{ij} \frac{1}{\sin\theta}$$

$$\mathrm{V}_{ij} = \sqrt{{V_i}^2 + {V_j}^2 - 2V_i V_j \cos\theta}$$

$$\mathrm{D}_{ij} = \frac{LiVj + LjVi}{V_{ij}} \sin\theta + Bj\left[1 - \left(\sin\theta \frac{Vi}{V_{ij}}\right)^2\right]^{\frac{1}{2}} + Bi\left[1 - \left(\sin\theta \frac{Vj}{V_{ij}}\right)^2\right]^{\frac{1}{2}}$$

In the above formulation, vessel I could be container liner, container barge and multi-purpose ship in Long Gu channel; and vessel J could be container liner and container barge in Western public channel; the angle θ between these two channels is 160 degrees; and according to table 3, causation factor P_C is $1.3*10^{-4.}$

Thus, the collision probability before Qian Hai Dredging Project F_b is about 201.5.

After the construction of Qian Hai Bay Dredging Project, sludge boat is transferring from construction area to Huang Mao Island for mud-dump, and according to the construction project, there are about 20 sludge boats per-day. Therefore, the vessel I in the formulation could be container liner, container barge, multi-purpose ship and sludge boat; the vessel J could also be container liner, container barge and sludge boat.

The collision probability after Qian Hai Dredging Project F_{A1} in the intersection of Long Gu channel and wester public channel is 258.3.

The data of traffic flow per day in Da Chan Bay approach channel and the temporary channel from Shenzhen MSA Navigation Management Department is (ships which is less than 50m are ignored here, such as fish boat and tug):

	Da Chan Bay approach channel	**temporary channel**
Container liner	2	0
Container barge	113	0
General cargo ship	46	0
Sludge boat	20	20

total	181	20

Table 7 Traffic flow in Da Chan Bay approach channel and the temporary channel

(from Shenzhen MSA Navigation Management Department)

The vessel I could be container liner, container barge, general cargo ship and sludge boat in Da Chan Bay approach channel; vessel J is sludge boat in the temporary channel. The angle θ between these two channels is 100 degrees.

The collision probability F_{A2} in the intersection of Da Chan Bay approach channel and the temporary channel is 11.37.

The comparison of the collision probability before and after Qian Hai Bay Dredging Project is in table 8 as follows:

<table>
<tr><td rowspan="2">Before</td><td colspan="2">Long Gu channel and western public channel</td></tr>
<tr><td colspan="2">201.5</td></tr>
<tr><td rowspan="2">After</td><td>Long Gu channel and western public channel</td><td>Da Chan Bay approach channel and the temporary channel</td></tr>
<tr><td>258.3</td><td>11.37</td></tr>
</table>

Table 8 Collision probability before and after Qian Hai Bay Dredging Project

(compiled by the author)

Conclusion from the above calculation, the collision risk is increased by 28% after the implementation of Qian Hai Bay Dredging Project; and in addition, a new collision risk of 11.37 appeared in the intersection of Da Chan Bay approach channel and the temporary channel.

However, it should be noted that the risk of grounding and the bad ship condition are not considered in this calculation, which means the actual impact of Qian Hai Bay Dredging Project will be even more higher. The statistics of maritime casualty in this water area just proved the influence. At the years of 2015 and 2016 when the Qian Hai Bay Dredging Project was under construction, the maritime casualty has an obvious rise in contrast with that of previous years.

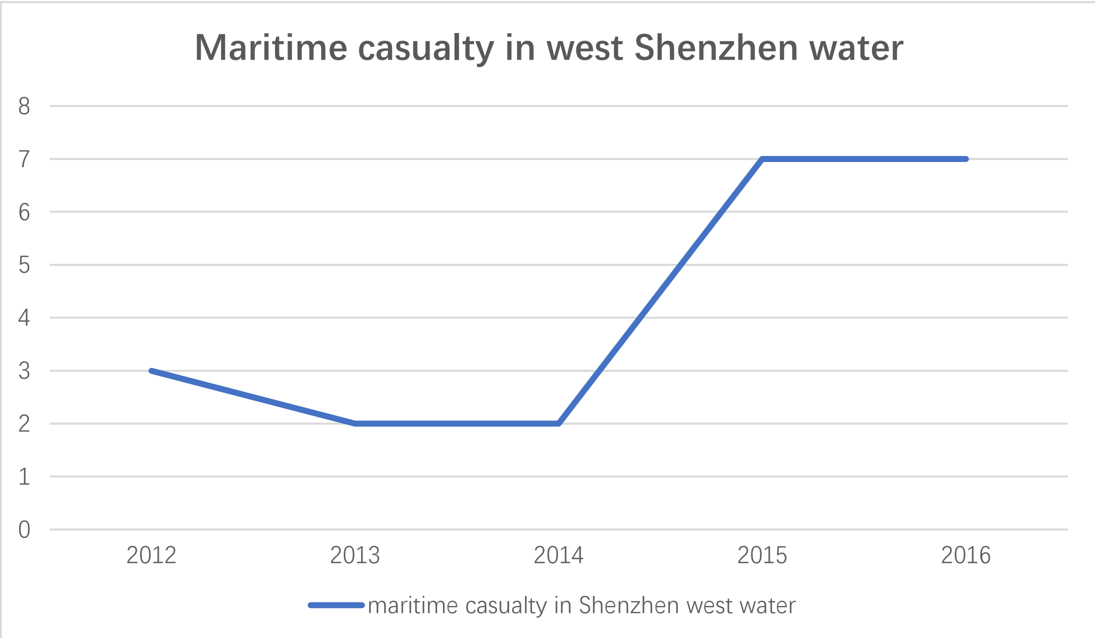


Figure 21 Maritime casualties in west Shenzhen water

(from Shenzhen MSA Safety Management Department, complied by the author)

Qian Hai Dredging Project is a representative but simplified case for the study of influence by ocean engineering on navigation safety, as there is only one main risk caused by sludge boat. However, in majority of ocean engineering, especially for coastal engineering, there are multiple problems except the increasing of traffic flow, such as the construction facilities which are located in the middle of channel.

Chapter 5

Recommendations

According to the above analysis, influence of ocean engineering, especially coastal engineering, on navigation safety could be divided into two categories: one of the most obvious and essential is the construction itself influence on navigation: construction operations often occupy navigable waters, and destroy the normal marine traffic rules (Zhou Yizong, 2005). Another type of influence is that construction operations produce permanent and temporary buildings or other underwater facilities, or change water flow, waterways, and some can seriously damage the navigation environment. To ensure the safety of the ship construction, reduce the impact caused by construction ship on other ships, the construction management departments, like engineering company, would develop the route management system, and necessary regulations, navigation management workers often use radar and VHF, mobile phone communication, etc. but it is not enough. There are mainly two directions to reduce the negative influence, safety management and technical innovation.

Safety management is a comprehensive system, which is designed to manage safety elements in the workplace. It includes policy, objectives, plans, procedures, organization, responsibilities and other measures (SSL, 2017). In the processing of ocean engineering, safety management consists of project management, construction unit management, construction vessel and crewmember's management, traffic organization and warning and emergency management (Wang Zhen, 2013). The basic framework of safety management is as follows:

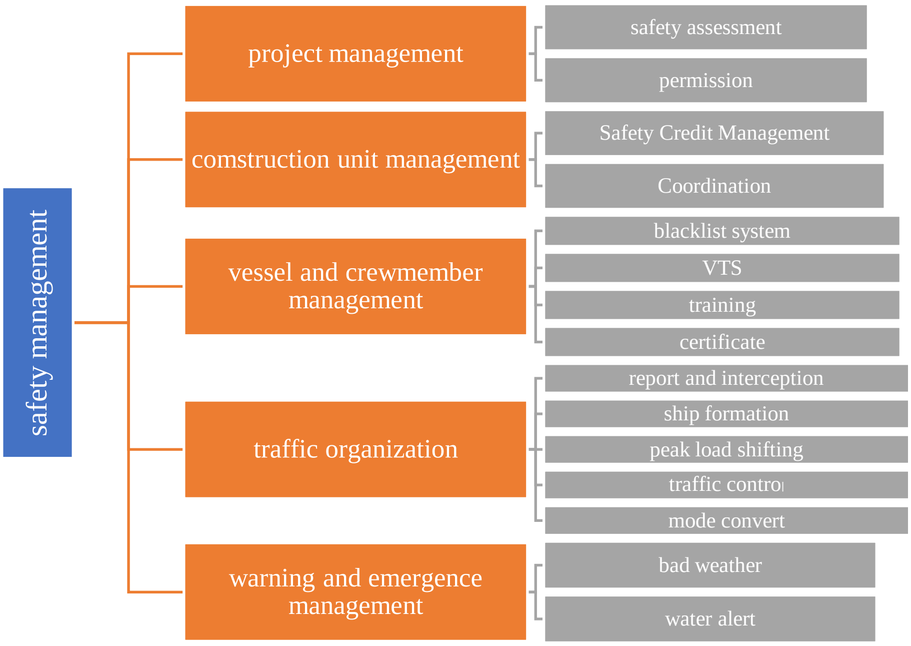


Figure 22 framework of safety management in ocean engineering

(from Wang Zhen, 2013, and compiled by the author)

Referring to technical innovation, which concerning about material science, construction technology, communication method, environmental protection, etc. in the following part, the application of AIS in ocean engineering will be emphasized.

5.1 Introduction of AIS

AIS (Automatic Identification System) technology, as a new method of ship navigation management, has been used more and more widely. An earlier method of communication was to send an information signal in a DSC (Digital Selective

Calling) manner to enable a ship equipped with a receiver or shore station equipment to automatically and continuously emit various inquiry information. A system with this function is referred to as "Transponder System" (Deng Hongzhang, 2002).

The ship automatic answering system based on DSC technology can improve the ship navigation safety, International Maritime Organization (IMO) adopted the "automatic ship identification transponder / transceiver system" resolution at the 74th S0LAS convention ninth contracting government meeting on November 29th, 1995 (IMO, 1995). The draft of ship automatic answering system was approved by IMO at the forty-second meeting of the Subcommittee on MSC in 1996. It was considered and referred to as "AIS". And the equipment of AIS is mandatory through SOLAS as: *"All ships of 300 gross tonnage and upwards engaged on international voyages and cargo ships of 500 gross tonnage and upwards not engaged on international voyages and passenger ships irrespective of size shall be fitted with an automatic identification system"* (SOLAS, 2009)

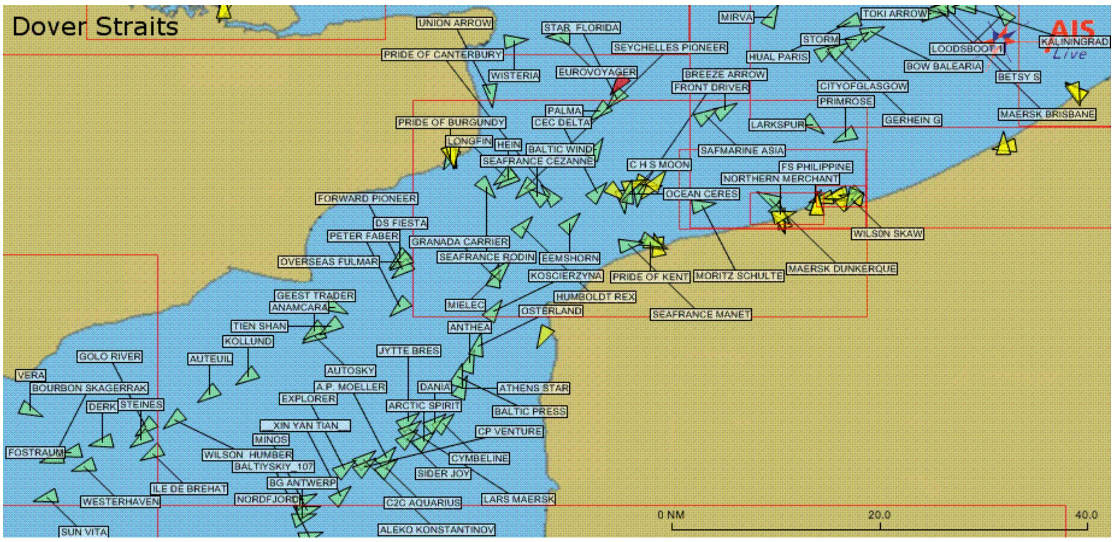


Figure 23 Automatic Identify System

(from AIS screenshot)

The basic functions of AIS are as follows:

1) AIS can automatically and continuously work without manual intervention, interchange the ship's dynamic information and static information (including ship identification number, name, type, position, course, speed, sailing and other ships and other information security related) between shore station or other ships;

2) automatic processing of all kinds of received information, and store and deal with the information;

3) received information could be displayed in the Vessel Traffic Service (VTS) screen and electronic chart, provides detailed visual information to the operator or management authorities, help managers to make correct operation of the crew or the operation of the ship;

4) Management department and other vessels can receive the status and position of ship through AIS, making accurate judgments on the ship's dynamic, tracking and monitoring the precise target ship. Different products have different working modes for users to choose from. In the automatic mode, the information about the state of the ship's safety will be sent out as soon as possible;

5) When exchanging data with the AIS shore station, the operator selects the broadcast release mode or the controlled response mode to adjust the time at which the AIS receives or transmits the information.

In short, AIS can prevent ship collision effectively, make the radar and VTS more powerful (Mei Xiong, 2006); static information and dynamic information within the coverage area of the ship can be displayed in the electronic chart, which improved the language of communication between vessels.

At present, the countries all over the world are actively developing the application of AIS. So far, the AIS network system in some areas has been built in a few developed countries (Chang S. J, 2004).

5.2 Application

In the three types of ocean engineering, deep-water offshore engineering is implemented under the sea or in the seabed, and there is almost no danger of navigation safety. Thus, the application of AIS focuses on coastal engineering and offshore engineering.

5.2.1 AIS and Offshore Engineering

Majority of offshore engineering is far from port and channels, but there are still some works, like drilling platform, located close to the channel, which may lead to a collision with ships due to bad weather or negligence. If a collision avoidance device is installed on the platform just like the ship, such as AIS and Automatic Radar Plotting Aid (ARPA), the dangerous ships near the platform can be found in time, so that the platform and the nearby vessels can identify each other, and the platform will play the role of navigation for the ship. It will avoid collision accidents to a large extent and ensure the safety of navigation ships and platforms (Li Yutian, 2014).

According to International Regulations for Preventing Collisions at Sea (COLREGS), the vessel shall be kept at least two nautical miles away from the object of obstruction in navigation. We could set the safe zone, control zone (green zone), and exclusive zone (red zone), and the distances are two nautical miles (yellow arrow), and 500 meters (green arrow) respectively, which is shown in the right part of below figure. Similarly, ship also has a two-nautical mile zone for navigation.

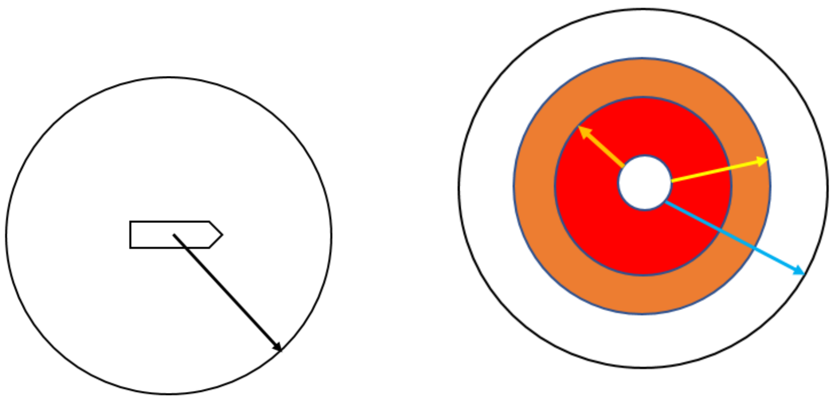


Figure 24 Navigation zone for ship and drilling platform

(compiled by the author)

From the relative position between the platform and the ship, the following part will explain how AIS could prevent collision:

1) the ship does not enter the control zone of drilling platform, normally, the distance from ship to platform is more than 25 nautical miles, and they could not identify each other as there is little risk of collision;

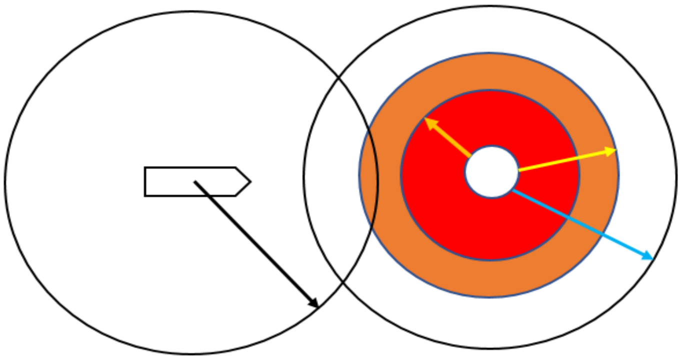


Figure 25 Ship is out of the AIS control area

(compiled by the author)

2) the ship has entered the control zone of drilling platform. The ship and drilling platform could identify each other through AIS; however, the ship is still safe in this area;

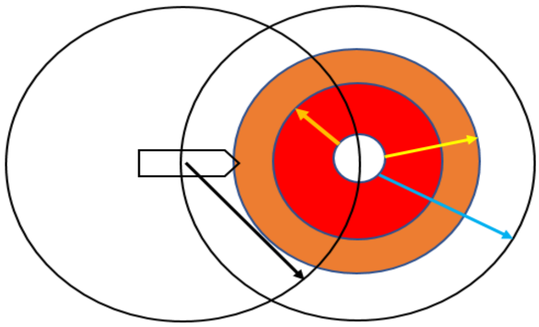


Figure 26 Ship enters the AIS area of platform

(compiled by the author)

3) the ship has already entered the control zone of platform. The ship should report to the platform control center, and obey the command. In addition, it is not allowed for

overtaking, encounter and dropping anchor in this area.

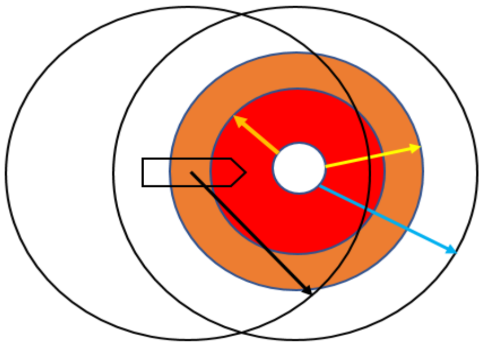


Figure 27 Ship has entered the control zone of platform

(compiled by the author)

4) the ship has entered the exclusive zone of platform, and is too close to the platform, which is extremely prone to collision accidents. The ship and platform should take measures according to the alarm information of AIS and ARPA and inform that no ship can enter the exclusive zone in advance.

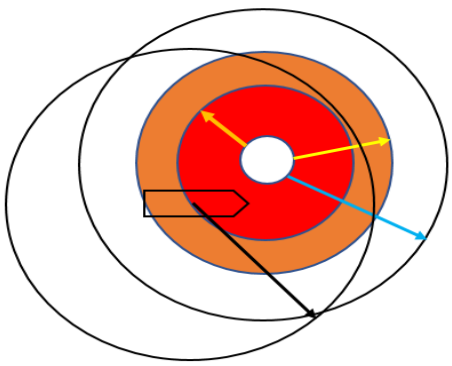


Figure 28 Ship has entered the exclusive zone of platform

(compiled by the author)

5.2.2 AIS and Coastal Engineering

It has analyzed in the previous chapter that coastal works has a negative impact on the navigation safety, especially increase the risk of collision accident. However, due to the features of coastal works, such as Qian Hai Dredging project, the size of construction ships is limited, a large part of the sludge boat is below 500 tons, which means it is not mandatory for this kind of ships to equip AIS according to SOLAS.

序号	船名	航区	总吨位（t）	净吨位（t）	参考载重吨位（t）	AIS 安装类别
1	藤县思中 206	B 级	470	263	800	B
2	粤中山货 2111	B 级	595	351	955	B
3	粤中山货 2275	B 级	90	31	96	B
4	粤中山货 2809	B 级	90	31	88	B
5	莞航 238	A 级	798	446	1189	B
6	粤南海货 3190	B 级	384	215	654	B
7	惠湾 389	沿海	1258	705	2000	A
8	粤南方 218	沿海	682	381	941	A
9	粤新会货 8210	沿海	495	277	714	A
10	粤新会货 1812	沿海	495	277	714	A
11	粤新会货 8199	沿海	495	277	714	A
12	苏扬驳 001	沿海	998	299	1373	A
13	惠新粤 118	沿海	493	276	646	A
14	江洋幸福 802	沿海	683	382	995	A

Figure 29 Partial ship information of Qian Hai Dredging Project, the green area is the Gross Tonnage of construction ships

(compiled by the author)

Before the start of Qian Hai Dredging Project, the authority had considered the impact on marine traffic of surrounding water. In the navigation safety assessment and process of work approval, the equipment of AIS for all construction ships is strongly recommended. Gratifyingly, the effect of AIS is also obvious:

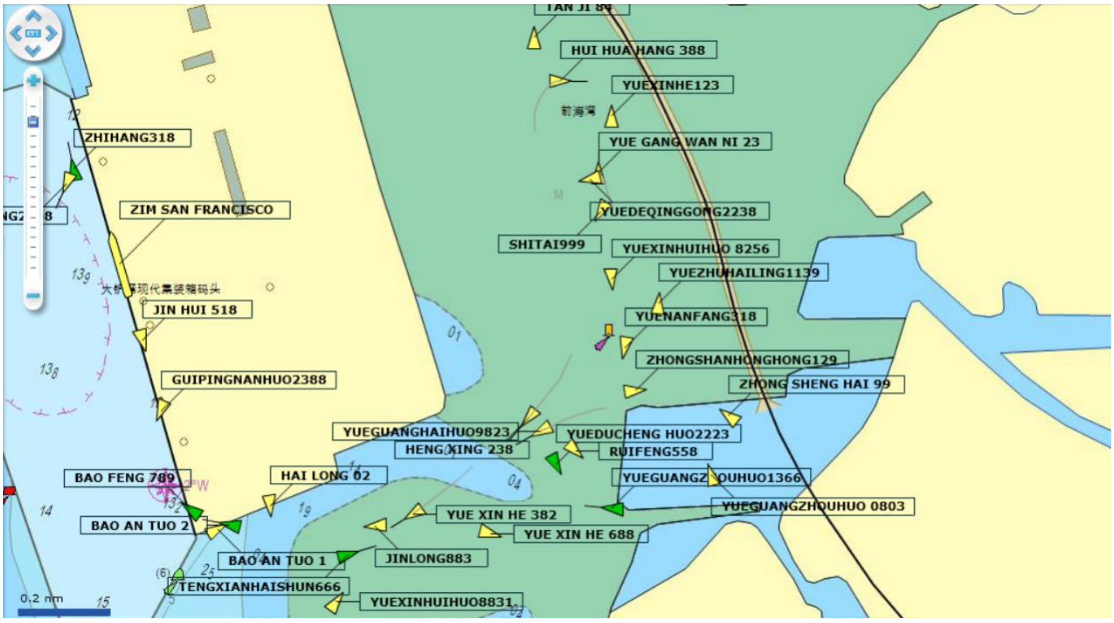


Figure 30 AIS display of construction area

(from AIS screenshot)

1) Through the network window AIS display system as shown as the above figure, the authority could carry out an effective monitoring on the construction area and all the construction ships; this can also help the company manager to arrange the ship globally, according to the ship's conditions, combining the maintenance plan and the ship arrangement to carry on the reasonable deployment to the construction ship;

2) Since the AIS system has been set up, it will operate in accordance with established procedures without the operation of the personnel. The AIS system will form a network system to transmit the navigation information of each other after other ships come into its coverage (Liu Zhigang, 2007), which is the same application in the drilling platform; in the project, the AIS system and ECDIS are combined, all kinds of information about the surrounding ships can be clearly displayed on the screen, to avoid and prevent the occurrence of ship collision accidents;

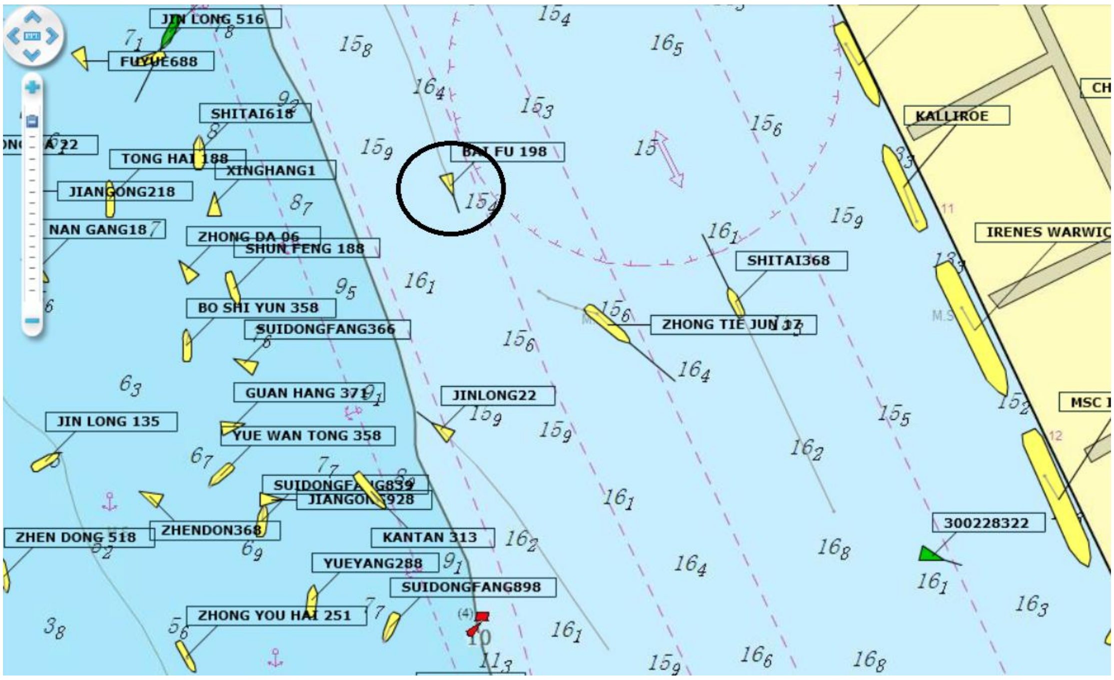


Figure 31 The information of surrounding ships, ship in black circle is sludge boat (from AIS screenshot)

3) When the construction ship is in danger, we must understand the location, cause, status of maritime accident ship, understand the dynamic surrounding waters of the ship, make a preliminary analysis of the judgment ability, and have a reasonable arrangement of resources for rescue as soon as possible. Using AIS, the authority and engineering company can obtain the information in time and implement the rescue immediately. There was an incident last month for a sludge boat in the process of mud transferring; the main engine broke down and lost power on the Long Gu channel, when there were three container liners left She Kou for Hong Kong through this channel. Because of the location information provided by AIS, the tug found the sludge boat and dragged it to safety zone.

Although the density of traffic flow in this water is high, and ship navigation environment is complex, from the process of works, there is no direct sailing accident between sludge boat and other vessels, which provides support for the smooth construction of the project, and provides a guarantee for the safety of the project (Xiao Yangchun, 2013).

Chapter 6

Conclusion

In twenty-first Century, one of the key areas of hegemony is ocean (Mo Jie, 2004), the other is space. In 2001, the official document of the United Nations put forward the notion “twenty-first Century is the ocean age”. Countries have introduced and adjusted their respective marine development strategies, and have invested more money and energy into marine development, which would bring a new surge of ocean engineering. The development of ocean engineering, such as technique innovation, environmental protection, material science, etc. among which, influence on navigation safety would inevitably attract more attention.

This paper introduces ocean engineering systematically, and some elements are closely related to navigation safety which are included in marine traffic engineering. On this basis, through the analysis of an actual case, Qian Hai Bay dredging engineering has presented negative influence on the surrounding waters by ocean engineering, especially by coastal engineering. In addition, with the use of IWARP model, the paper gives a quantitative calculation and research on the impact from the point of increased collision probability caused by the booming of construction ships.

AIS is a new navigational equipment, whose application in ocean engineering has greatly widened the communication channel between ship-ship and ship-shore. It is more convenient for the crew and engineering managers to obtain the shipping condition and navigation information, and reduce the negative impact of ocean engineering on ship navigation effectively.

However, this paper does not cover the issue of ocean engineering supervision, such as how the maritime authorities prevent and investigate illegal dumping of mud which will also endanger the safety of navigation. With the development of Qian Hai Bay dredging project, and the strengthening of supervision, the writer hopes to continue the research study in the future, and propose new solutions and recommendations to minimize the influence of ocean engineering on navigation safety.

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